

Bridging the Gap Theory-Current Practice

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INTRODUCTION

Modern highway engineers have designed and constructed the greatest road system the world has ever known. This accomplishment is a credit to the individuals and to our profession as a whole. It is entirely proper for us to brag about our past accomplishments and the good jobs that we have built.

We must, however, remember that terms such as “good”, “excellent”, and “satisfactory” are only relative; they indicate a comparison between the present and the past. The real challenge is to compare the present with our possibilities in the future. The good pavement of today may be judged only fair in light of what we expect to produce tomorrow.

There is no question as to whether or not we are moving forward—undoubtedly the pavements of tomorrow will be superior to those constructed yesterday. However, being the impatient type of humans that we are, concern is with maximizing the rate at which these improvements are accomplished. We acknowledge that our long range basic research effort must be expended and intensified. We know also, however, that there is an urgent need to bring into focus the vast amount of existing technology and translate this information into current designs, specifications and construction practices.

DESIGN BETTER THAN PRODUCT

It has been said that the engineer’s theoretical design knowledge is twice as good as the product he describes in his specifications. Further, that the product specified is three times as good as the product actually constructed in the field.

You may question these numerical ratios between theoretical knowledge, specifications and final product, however, I am sure that you will acknowledge that there is today an enormous gap between available theory and construction practices.

How to Bridge the Gap?

How do we bridge this gap? If you asked an engineer concerned solely with design, he would reply "... more rigid inspection—make the contractor and supplier perform in accordance with the specifications." However, if you asked a construction supervisor, the answer would be "... turn out designs and specifications that face up to practical construction problems—that are realistic and possible to administer with the inspection forces assigned to a project". Both of these points of view are pertinent. In effect, they confirm that there is a "gap".

They also indicate that the problem of "bridging the gap" is not a simple one; it requires an analysis of the entire engineering process involved in the advancement of a highway project.

Three Tasks of the Engineer

We can characterize the engineer's work effort as three tasks: designs, specifications and inspections.

- (1) Decisions as to what he wants—giving consideration to all economic and other factors—designs that will best fulfill the needs.
- (2) Descriptions of what he wants—plans, specifications and defining details necessary to move the project to the construction phase and serve as a contractual document between buyer and seller.
- (3) Verification of what he receives—procedures for inspecting, sampling and testing the product received to assure that it is in conformance with the descriptions of what he wanted.

Each of these three tasks concerns the common problem of "product identification." We must identify, during design, what we *want*; we must identify this *want* in our specifications; and, we must identify the product we receive. All aspects of product identification must mesh together—there must be a *fit*. The identification noted in our designs and specifications must be in terms that can be verified by measurements and observations during construction inspection.

In my opinion, to bridge the gap between existing technical knowledge and current practices, to move our improvement program ahead as rapidly as possible, we must focus our attention on the need for compatibility between specifications and inspection procedures.

The design engineer is correct—we do need more rigid inspection. However, as noted by the construction supervisor, our specifications must be practical to administer.

A NEED TO IMPROVE SPECIFICATIONS AND INSPECTION

There is an enormous effort being made today to improve our specifications and inspection procedures. There appears to be a feeling of urgency to solve these problems. I have asked myself, why? Why, almost overnight, have these subjects demanded our attention? I suggest that there are three major reasons:

Increase in Highway Construction

The enormous increase in the highway construction program has skyrocketed our industry in the category of "big business." This change has required the adoption of more formal business procedures for all aspects of our activities. Using management's terminology, decision making at all levels of responsibility must be subjected to audit. In engineering terms, decisions as to the acceptability of materials and construction items, must withstand an objective comparison of "what we requested" in our specifications, and "what we received" at the project site. Documentation must be provided that permits a complete review and audit by program management.

This requirement for audit, for confirmation, for verification, has demanded the development of specifications and quality control procedures that are specific, and, to the maximum degree possible, quantifies all items by measurements.

New Technology

New technology provides a better scientific understanding of the desirable properties of our materials. We have recognized the usefulness of the theories of statistics in identifying the variability of our products. We have many new measurement tools. Our contractors, manufacturers and suppliers have available a new generation of automatic and electronic equipment. All of us in the highway industry are eager to explore and apply these new technologies and advancements.

Lack of Engineers

The third factor is manpower. Today, we must devise inspection, sampling, testing and decision-making procedures that can be reliably progressed by technicians with only minimal training. We can no longer be assured of frontline manpower with the background and experience necessary to make so-called engineering judgments.

In many instances, the type of quality control system suitable for a particular product will depend upon the caliber of personnel that can

be assigned to the required inspection. That is, the control procedure must recognize that the required sampling, testing and decision making may be done by an inspector with limited technical capacity.

In the past, many of our inspection tasks were done by experienced engineers; today, the technicians must take over. Since even technicians are scarce, we should attempt, wherever possible, to use mechanical equipment and devices as substitutes for the technicians.

I believe that any one of these three factors provides adequate justification for our current emphasis on the subject of quality control. As professionals we are anxious to use the new technologies, we recognize that the requirements of big business in regard to audit and documentation of our decision making, and, we regrettably acknowledge that there is a severe manpower shortage.

EXAMPLES OF BRIDGING THE GAP IN N.Y.

Bridging the gap between theory and current practice involves not only a multitude of technical considerations but also the problems of business, management and manpower.

In New York we fully recognize and acknowledge the need to update our designs, specifications and inspection procedures.

Together with our manufacturers, suppliers and contractors we are examining aspects of our work. We have made some progress but we still have much to do. It may be that a few examples of our efforts would be of interest.

Paving Grade Asphalt

Our specifications require 85-100 penetration asphalt for hot plant mix bituminous concrete. About four years ago we decided to obtain samples of asphalt from the feed-line between the mix-plant storage tank and the pugmill rather than sampling at the refinery which we had done previously. This was a change in sampling location only. It raised the question, however, as to how good a "fit" we could expect between our specification limits of 85-100 and the test values on samples taken at this new location. Could we rigidly enforce the 85-100 limits or was there need for a "tolerance" beyond these limits?

On the basis of our recent analysis of 1966 data, rigid enforcement of the 85-100 limits would have resulted in more than 20 percent rejections. Certainly this is no "fit" the specifications are too restrictive, these limits cannot be enforced.

Test data indicate that with our control procedures, the reasonable penetration limits are 75 to 110—a 35 point spread rather than 15 points. With these broader limits we now have a “fit” between specifications and inspection procedures.

Liquid Asphalts—Cutbacks and Emulsions

To further emphasize this idea of a “fit” or compatability between specifications, inspection, sampling and testing—we have analyzed our data on liquid asphalts (MC cutbacks and MS emulsions). As is the case with the paving grade materials, we sample at the point of usage, the mix-plant pugmill or the distributors at the project for spray applications.

We find that these materials have a normal range of 75 points for the penetration of the residue. Our current specification requirements for penetration are 100-200 for MS emulsions and 120-250 for MC cutbacks—ranges of 100 and 130, respectively. In this case we have a “fit” under current production procedure, the material we received should be expected to be within specification limits; if it is outside these limits a rejection is issued.

Bituminous Concrete

About seven years ago we made a rather extensive study of specifications and inspection procedures for plant mixed bituminous concrete. A high frequency sampling and testing program furnished data as to the characteristics and uniformity of the product we were receiving. Some interesting facts were disclosed that permitted changes in our specifications and inspection procedures.

1. With the aggregates and plant screening equipment normally used in New York, it was not possible to consistently produce gradations that were within the specified tolerance limits for minus No. 20 and No. 40 screens.
2. The required minimum mixing time was excessive; fully coated material could be obtained with a shorter mixing period.
3. Variations in the gradation of mixes and the percent of asphalt were directly assignable to errors or mistakes of the batching operator.
4. Sieve analyses of hot bin samples adequately describe the gradation of aggregates larger than the No. 80 sieve; for the percent of material finer than the No. 80, extracted samples of the final mix should be used.

5. On the basis of extraction tests, variation in asphalt content are at least plus or minus four tenths percent.

As a result of these findings we have broadened the specified gradation tolerance for the No's. 20 and 40 screens; it is now practical to consistently meet these requirements. We have based our mixing time requirement on the Ross Count test which determines adequacy of coating; for modern equipment, less mix time is required than previously. We have required that the proportioning operation of all mix plants, either by weight or volume, be fully automated with over and under cut-off switches, and, that the delivered amount of each sized aggregate and asphalt be recorded automatically.

One inspector is assigned to the plant. His major concern is with the gradation of the mix. His procedures of operation are described as follows:

The aggregate within each hot bin is identified by its "primary size," for example, a $\frac{1}{2}$ -inch primary size would indicate that not less than 70 percent of the material in that bin passed the $\frac{3}{4}$ -inch sieve but was retained on the $\frac{1}{2}$ -inch sieve.

A coarse aggregate bin is considered uniform when the percent of primary size aggregate in that bin does not vary more than plus or minus 12 percent from the last analysis, and when the primary size aggregate in that bin comprises at least 70 percent of the bin material. A fine aggregate bin is considered uniform when the percent of aggregate in that bin passing the $\frac{1}{8}$ -inch sieve and retained on the No. 20 sieve does not vary by more than plus or minus 12 percent from the last analysis. Note that the aggregate testing for "primary size" involves only 2 screens—the procedure is simple and rapid.

As long as the uniformity tests indicate satisfactory gradation, we continue to run one test for every 100 batches. Should any test indicate non-uniformity, gradation outside the stated limits, another analysis is immediately run. If the results of this second test are also outside the limits, production is unacceptable and the plant is shut down.

The producer, after making required adjustments to equipment or procedures, requests a new sampling. If the test results for this sample are within the stated limits, production is resumed.

It appears at the present time this package deal for bituminous concrete batch plants, specifications and inspection procedures, offers adequate assurance that we are receiving the material we want, is not over restrictive on the producer, and, can be implemented with a minimum of manpower.

Density of In-Place Bituminous Concrete

Quite often an analysis of data concerning the identification of a product comes up with surprises. Studies in New York have related the in-place density of bituminous concrete to such factors as gradation of the mix, asphalt content, rolling effort, mix temperature, and, other variables. The results, within the range of variations in work procedures (rolling effort, mix temperatures, etc.) that might be expected on a normal well-run project, show that pavement densities are most significantly related to variation in the asphalt content and gradation of the delivered mix. A practical quality control conclusion might be to emphasize product uniformity at the mix plant. In other words a density requirement is not needed in the specifications.

Compaction of Embankments and Base Course

The establishment of quality control procedures for any material requires the accumulation of a lot of data to identify the characteristics of the materials. Frequently, an analyses of these data indicate that there is a wide range of variability in our product. For compaction control at the AASHO Road Test, eight density tests were run on each embankment block each of which was 800 feet long, 28 feet wide and 4 inches deep. This sampling frequency is equivalent to one test per 34 cubic yards of material placed or one test for the material delivered by two big hauling units. This rate is, of course, impractical for normal highway construction. The question to be raised at this point is whether or not the measurement tool that we now have to judge degree of compaction is truly adaptable as a quality control device. If the rate of sampling and testing used at the AASHO Road Test is required to adequately identify the variations in density of our embankments, we had better find a substitute or supplement for our present procedures.

One supplemental approach to embankment and base course control is "proofrolling." In New York, we are making limited use of this measurement tool at the present time. Perhaps it has wider applicability.

Cement, Reinforcing Bars, Pavement Mesh and Paint

The inspection procedure usually referred to as "inventory control" is clean-cut to administer but sometimes costly. A sample of a particular "lot" of material is inspected and sampled at the point of manufacturing. The sample is tested and, if found satisfactory, tagged or otherwise identified prior to shipment to the construction site. In New York, we exercise inventory control on cement, reinforcing bars, pavement mesh, paint and several other items. This procedure has the advantage of only approved materials being delivered to the project.

SUMMARY

In closing—I have suggested that we need to “bridge the gap” between on-hand theoretical knowledge and current practice. We must remember that a great many of the acceptability conditions noted in current specifications were developed by states or industry under controlled conditions available only in the laboratory—their field applicability has not been tested.

There must be a “fit” between specification and inspection procedures. We cannot specify materials that cannot be measured by both ourselves and the producer. We must define, in writing, exactly how we will sample, how we will test, and how we will interpret the test data to arrive at a decision in regard to acceptability.

We must document all aspects of engineering decision making to the degree that it will withstand audit of management. We must conserve engineering manpower.

The nationwide emphasis now being given the general subject of quality control will revolutionize the highway construction industry. We will find and correct our weaknesses and inaccuracies. We will discard antiquated machinery and processes and we will substitute facts based on measurements for opinions.